N91-28112

COMPUTER SIMULATION OF RADIATION DAMAGE IN GALLIUM ARSENIDE

549-76
26630
P7

John J. Stith, James C. Davenport, and Randolph L. Copeland
Department of Physics
Virginia State University
Petersburg, Virginia

ABSTRACT

A version of the binary-collision simulation code MARLOWE has been used to study the spatial characteristics of radiation damage in proton and electron irradiated gallium arsenide. Comparisons made with experimental results have proved to be encouraging.

COMPUTER SIMULATION OF RADIATION DAMAGE IN GALLIUM ARSENIDE

The main objective of this research is to study radiation damage and annealing in gallium arsenide through the use of computer simulation.

Electronic devices manufactured from semiconductors are vital to the space program. These devices must be capable of surviving and operating in an environment where various types of radiation are present. In order to design the devices for maximum tolerance to the radiation encountered in the space environment, the damaging effects of the radiation on the semiconductor must be studied. Extensive laboratory testing and/or computer simulations of the effects of the specific radiation on the semiconductor are required. The present study was done with computer simulation.

Gallium arsenide has received considerable attention over the past few years due to its potential usefulness in high-power space-energy systems where high operating temperature is a limiting factor for other semiconductors. However, space radiation may be a limiting factor unless sufficient shielding is provided to keep damage levels within acceptable limits.

In order to determine design parameters for a specific space environment, a fundamental understanding of specific radiation interaction with the semiconductor is required.

On impinging upon the semiconductor, radiation produces a variety of defects. The defects which are of the most interest to researchers include interstitials, vacancies, vacancy clusters, and improper replacements for binary crystals such as gallium arsenide. There are at least three classes of electrically active defects that are produced in gallium arsenide, and they are the following: (1) those that do not anneal (including improper replacements, some distant interstitial-vacancy pairs, and some vacancy clusters), (2) those that anneal at relative low temperatures, and (3) those that anneal at high temperatures.

In space, simultaneous radiation exposure and annealing might result in very limited degradation because the duration of radiation exposure is many mean-annealing-times. A terrestrial experiment to verify this would be inconclusive since the usual duration of radiation exposure will be less than the required annealing time. A laboratory experiment which properly simulates the effect of simultaneous irradiation and annealing in space would be costly and difficult. Computer simulation provides a convenient technique for studying atomic scattering in crystals. It is particularly useful at moderate energies where crystal effects may be pronounced, but where clear distinction between random and aligned processes is difficult.

A theoretical understanding of the effects of displacements in semiconductors caused by radiation requires a detailed analysis of the dependence of the number of point defects and their spatial distribution on the energy of the primary recoil atom.

The binary-collision simulation code MARLOWE has been modified to run on NASA LaRC computer system and used to simulate radiation damage produced in a gallium arsenide crystal when it is irradiated with electrons and protons. Primary recoil atoms possessing energies corresponding to the average energy transfer between a 1-Mev electron and a gallium or arsenic atom, and primary recoil atoms possessing energies corresponding to the average energy transfer between a 100-Kev proton and

a gallium or arsenic atom were used to start the displacement cascades in the crystal. The 1-Mev electron is used in the equivalent fluence testing of devices and the 100-Kev proton has been shown through theory and experiment to be most effective in damaging the .5 and .8 micron junction gallium arsenide solar cells.[2,3]

The results from the computer simulations yielded information on the spatial distribution of the defect pairs (close pairs, near pairs and distant pairs), as well as details on possible clusters of defects, such as multiple vacancies.

Analysis of vacancy-interstitial pairs was made. The graphs in figures 1 and 2 show the distribution of the separations of the pairs for the 20 and 90 eV recoil energies, respectively. The distributions include close, near, and distant pairs. When the distributions on the two graphs are compared, it is clear that there is a greater number of interstitial-vacancy pairs for the higher-energy cascades than for the lower-energy cascades. Figures 3 and 4 are included to show the relative positions of the interstitials and the vacancies produced in the crystal. Close, near and distant pairs are displayed. In figures 5 and 6 the close pairs are not included since it is a good possibility that the vacancies and interstitials that form the close pairs will combine (self-anneal). Figures 7 and 8 only display the distant pairs which may still exist after annealing of the crystal which stimulates the near pairs to combine. When a proper pair combines, two defects are eliminated, but when an improper pair combines, two defects are reduced to one defect which is different from either of the two original defects. The distant pairs will most likely remain as stable defects within the crystal even through the annealing process. There is a sizeable difference between the number of distant pairs for the high-energy primary recoil atoms. This is in good agreement with the experimental results that demonstrated a high degree of difficulty in annealing proton radiation damage as compared with annealing electron radiation damage in gallium arsenide.

References

1. Robinson, M.T. and Torrens, I.M.; Phy. Rev. B, 1974, 9(12), 5008.

2. Stith, J.J. and Wilson, J.W.; Proc. of the Eighteenth IEEE Photovoltaic Specialists Conf., 1985, 1716.

3. Wilson, J.W., Walker, G.H., and Outlaw, R.A.; IEEE Electron Devices, 1984, Vol. 31, 421.

4. Benedek, R.; J. Appl. Phys., 1981, 52(9), 5557.

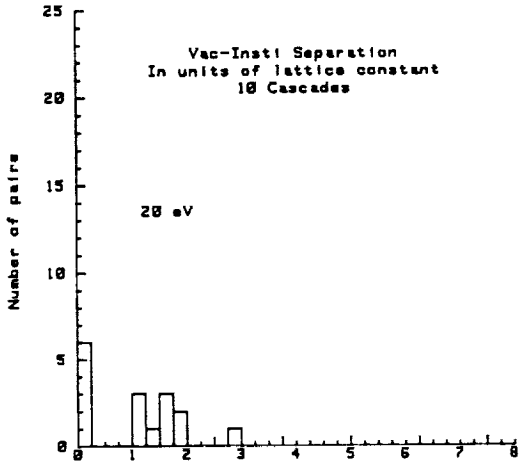

Figure 1

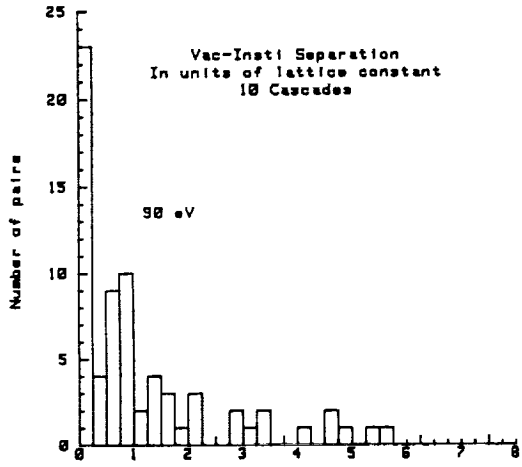

Figure 2

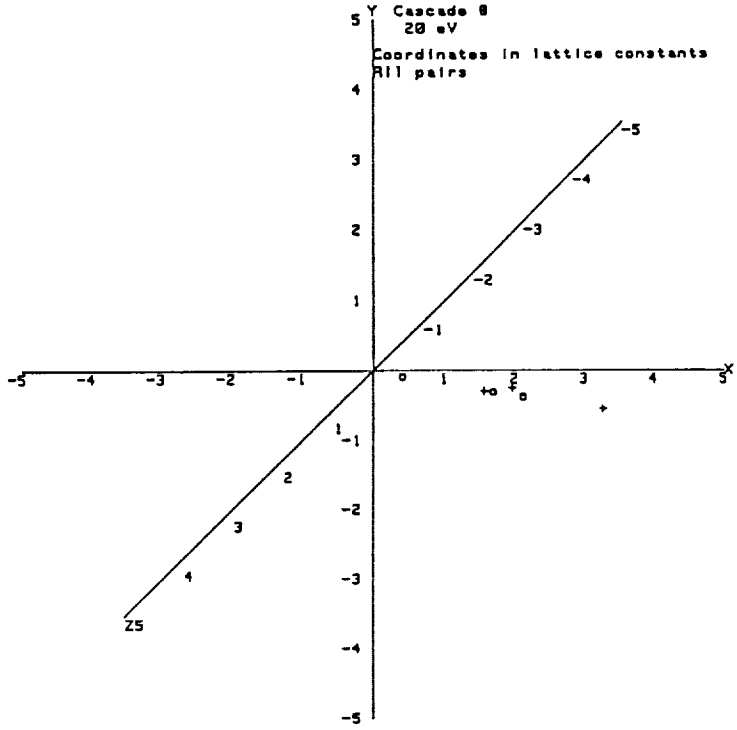

Figure 3

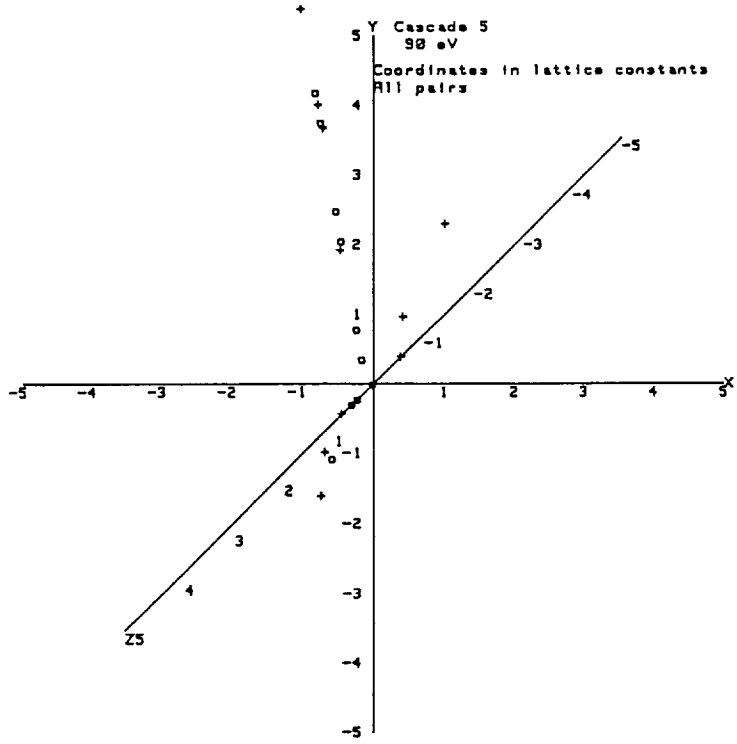

Figure 4

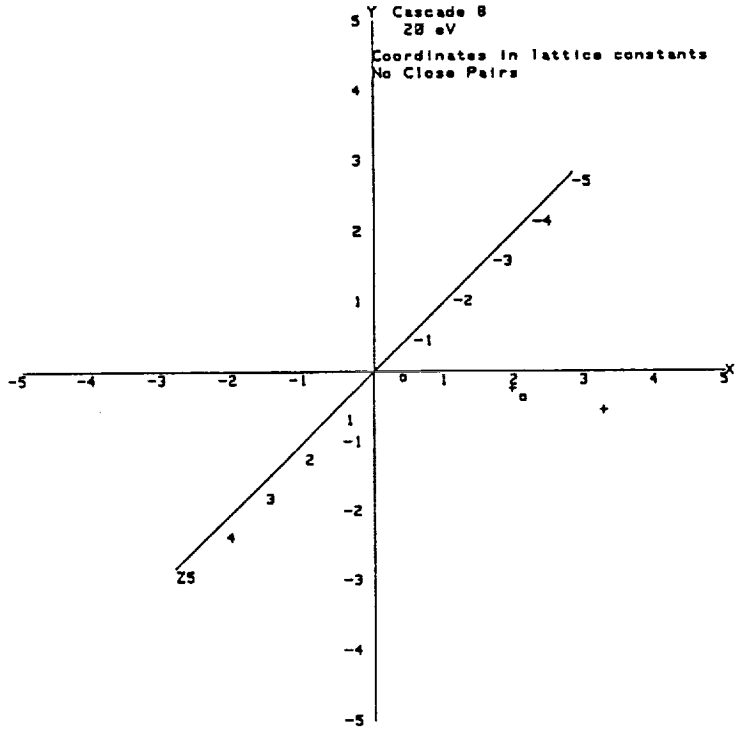

Figure 5

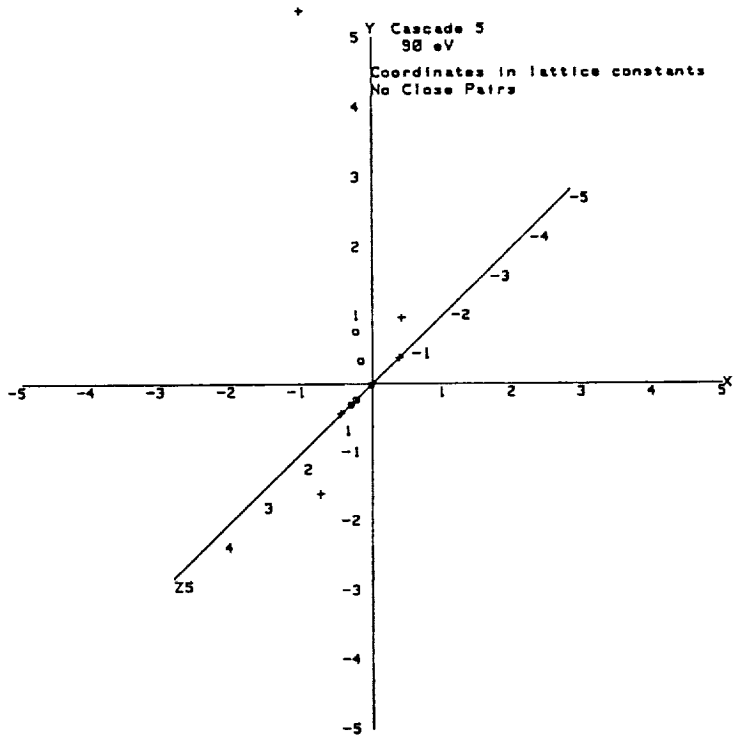

Figure 6

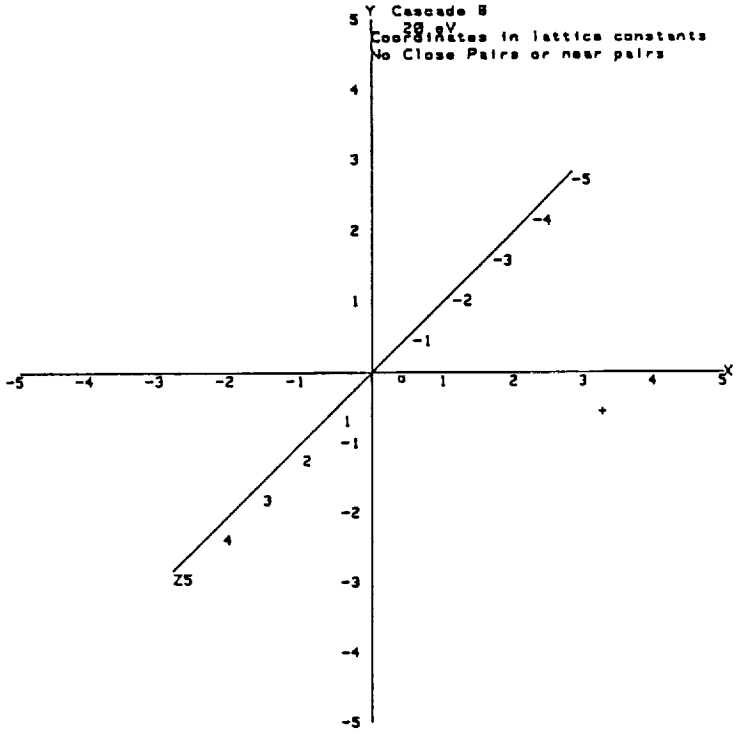

Figure 7

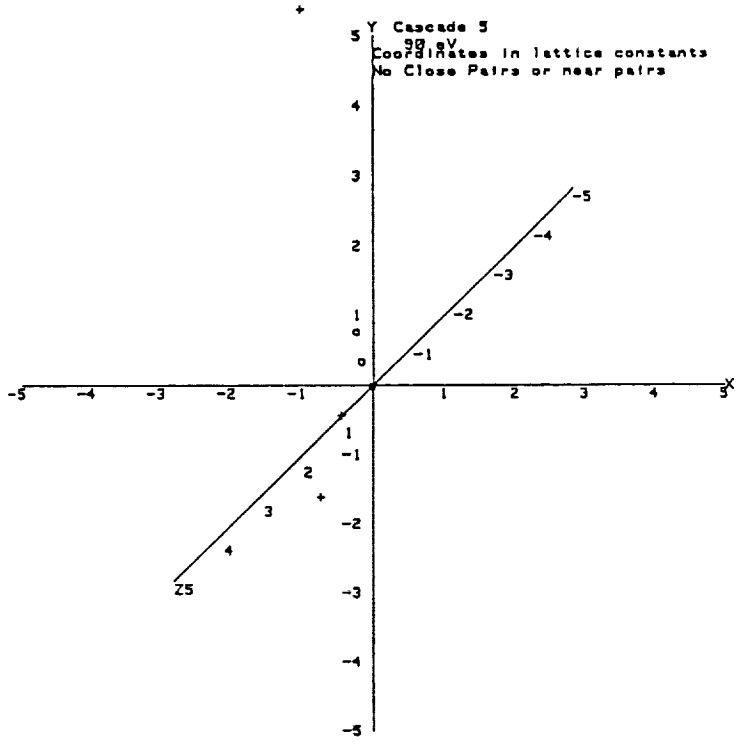

Figure 8

ORIGINAL PAGE IS
OF POOR QUALITY